PB82-143249

Pollutant Monitoring in the Olympic National Park Biosphere Reserve

(U.S.) Environmental Monitoring Systems Lab.
Las Vegas, NV

Dec 81

U.S. Department of Commerce
National Technical Information Service
NTIS.

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before complet

1. REPORT NO. EPA-600/J-80-039	2. Journal Article	3. PB82-143249
4. TITLE AND SUBTITLE POLLUTANT MONITORING IN THE OLYMPIC NATIONAL PARK BIOSPHERE RESERVE		5. REPORT DATE December 1981 6. PERFORMING ORGANIZATION CODE 2362021
7. AUTHOR(S) Kenneth W. Brown		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS Environmental Monitoring Systems Laboratory Office of Research and Development U.S. Environmental Protection Agency Las Vegas, Nevada 89114		10. PROGRAM ELEMENT NO. 11. CONTRACT/GRANT NO.
12. SPONSORING AGENCY NAME AND ADDRESS U.S. Environmental Protection Agency--Las Vegas, NV Office of Research and Development Environmental Monitoring Systems Laboratory Las Vegas, Nevada 89114		13. TYPE OF REPORT AND PERIOD COVERED Journal Reprint 14. SPONSORING AGENCY CODE EPA/600/07

15. SUPPLEMENTARY NOTES

Printed in Environmental Monitoring and Assessment 1 (1981) 37-47

16. ABSTRACT

Interest in global contamination has been instrumental in the establishment of over 33 Biosphere Reserves in the United States. These reserves include pristine areas that have been protected from industrial development. They serve as areas in which present and future environmental pollution can be assessed.

Pollutant monitoring studies are being conducted in the Olympic National Park Biosphere Reserve by the U.S. Park Service and the U.S. Environmental Protection Agency. Studies are designed to identify levels of trace element and organic contaminants in physical and biological media. Ten remote sites were selected for intensive sampling. These areas were located in the Hoh, Quinault, and Dosewallips River drainages; at Anderson and Grand Pass; near Ozette Lake and, at the northern edge of Blue Glacier. Their proximity to vehicle-traveled roads varied from 3 to 20 kilometers.

Samples were taken in air, water, soil, litter and vegetation. Samples will be analyzed for organic and heavy metal contaminants. Airborne particulate size and chemical characterization is being investigated.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group

18. DISTRIBUTION STATEMENT RELEASE TO PUBLIC	19. SECURITY CLASS *(This Report)* UNCLASSIFIED	
	20. SECURITY CLASS *(This page)* UNCLASSIFIED	22. PRICE

EPA Form 2220-1 (Rev. 4-77) PREVIOUS EDITION IS OBSOLETE

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA 22161

EPA-600/J-80-039
Journal Article

POLLUTANT MONITORING IN THE OLYMPIC NATIONAL PARK BIOSPHERE RESERVE

KENNETH W. BROWN

Exposure Assessment Research Division, Environmental Monitoring Systems Laboratory, U.S. Environmental Protection Agency, Las Vegas, Nevada 89114, U.S.A.

Abstract. Interest in global contamination has been instrumental in the establishment of over 33 Biosphere Reserves in the United States. These reserves include pristine areas that have been protected from industrial development. They serve as areas in which present and future environmental pollution can be assessed.

Pollutant monitoring studies are being conducted in the Olympic National Park Biosphere Reserve by the U.S. Park Service and the U.S. Environmental Protection Agency. Studies are designed to identify levels of trace element and organic contaminants in physical and biological media. Ten remote sites were selected for intensive sampling. These areas were located in the Hoh, Quinault, and Dosewallips River drainages; at Anderson and Grand Pass; near Ozette Lake and, at the northern edge of Blue Glacier. Their proximity to vehicle-traveled roads varied from 3 to 20 kilometers.

Samples were taken in air, water, soil, litter and vegetation. Samples will be analyzed for organic and heavy metal contaminants. Airborne particulate size and chemical characterization is being investigated.

1. Introduction

A study was initiated to identify pollutant concentrations in specific biological and physical samples in the Olympic National Park for the development of a pollutant monitoring system. This study, similar to that conducted in the Great Smoky Mountains National Park as described by Wiersma *et al.* (1979), is a cooperative effort between the U.S. Environmental Protection Agency's Environmental Monitoring Systems Laboratory at Las Vegas (EMSL–LV) and the National Park Service (NPS).

Olympic National Park, a public reserve of 360 041 hectares (ha), is one of more than 33 designated biosphere reserves in the United States. The concept and criteria used to establish this reserve system have been previously described by Franklin (1977). Basically, the biosphere reserve sites are physically and biologically undisturbed and protected natural background areas where life processes occur with minimal human interference. They are of value because they:

1. provide permanent and undisturbed areas in which long-term background or baseline studies can be conducted on environmental and biological features;
2. are natural sources of genetic pools of animal and plant species;
3. provide areas for assessing, identifying, and recording the physical and biological state of the environment;
4. provide endemic habitat to obtain data from local environmental studies instrumental for the formation of management plans and policies for the reserve;
5. provide areas for long-term biological research; and
6. serve as sites for measuring and assessing the concentration and impact of manmade pollutants on biological systems.

Environmental Monitoring and Assessment **1** (1981) 37–47. 0167–6369/81/0011–0037$01.65.

The use of biosphere reserves as pollutant monitoring sites originated with the Man and Biosphere program (MAB) at the 16th General Conference of the United Nations Educational, Scientific and Cultural Organization (UNESCO) and with a 1970 Ad Hoc Task Force concerned with the Global Network for Environmental Monitoring (GNEM). The recommendations, criteria, and coordination of these groups was previously described (Wiersma and Brown, 1979).

Experimental design, methods, and approach used for collecting data to develop a pollutant monitoring system for the Olympic National Park follows the basic principle of the monitoring systems design described by Schuck and Morgan (1975) and Morgan *et al.* (1979). This approach addresses sampling and analysis of pertinent biological and physical components and the identification of the interactions occurring between these components. Methods for assessing and addressing the systems concept using kinetic modeling have been described by O'Brien (1979) and Barry (1979). Wiersma (1979) applied this method to the analysis of lead in the Great Smoky Mountains National Park.

This report describes and identifies the sampling locations, samples collected, equipment used and preliminary findings from the summer 1979 project in Olympic National Park. The objectives are to determine pollutant levels, assess variability between collected samples, determine biological accumulators of selected contaminants and evaluate sampling equipment.

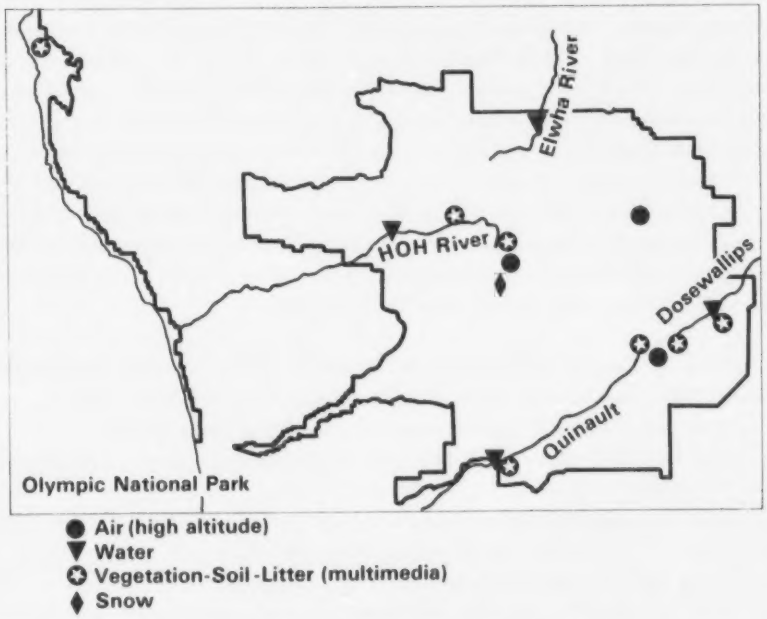

Fig. 1. Sampling locations in the Olympic National Park.

2. Methods

To sample this biologically diverse national park, a variety of sampling sites were picked (Figure 1). On most of these sites coordinated sampling was carried out in air, soil, water, vegetation and forest litter. In general two sampling sites were established in each of three river drainages in the park, the Hoh River, the Quinault River and the Dosewallips River. One site was located on the coast. These sites were supplemented by additional air sampling sites and water sampling sites. Figure 2 shows the distribution of sites in the Hoh River and also demonstrates how each site was sampled.

The major route of entry of pollutants into the park is the air pathway. As such, emphasis is placed upon the methods and means to collect and measure airborne contaminants. This is especially important in the Olympic National Park, in that, even though the predominant air masses originate to the north and northwest, the local topography influences the air flow to a great extent. As reported by Moorehead (1979) the air flow is effected by the conical shape of the local terrain. This phenomenon can create problems in assessing contaminant impact from large incoming air masses versus that from possible transport and redeposition by local meteorological conditions.

The techniques and procedures for sampling air in biosphere reserves have been previously described by Brown *et al.* (1979) and Wiersma *et al.* (1980). A Dupont P4000A air pump, with a maximum flow rate of 4000 cc min^{-1}, is used. The power

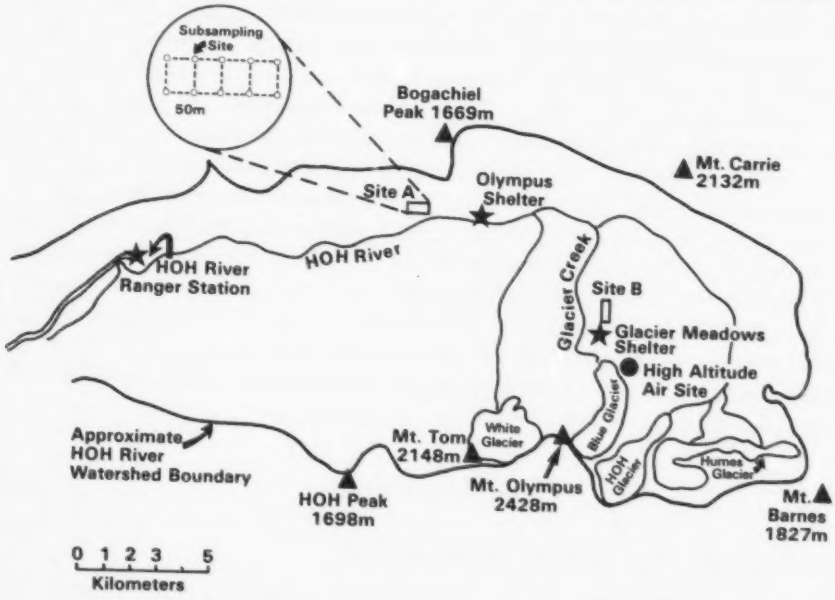

Fig. 2. Sample site and subsampling site design for the Hoh River.

source, which can operate the air sampling equipment for 10 continuous days, are Gates® sealed acid batteries.

The air sampling devices used to collect particulate samples at each air sampling site consisted of combinations of plastic Millipore aerosol monitors and stainless steel holders. Both types are loaded with 47-mm diameter Millipore filters having a 0.45-μm pore size.

Four air samples are collected per site. The duplication is due to three different analytical procedures used to identify trace-element contamination: X-ray fluorescence, atomic absorption spectrometry, and scanning electron microscopy (SEM). The fourth sample is archived in case of loss or for further analytical requirements. Prior to use, all stainless steel holders and filter membranes are cleaned and packaged in a clean laboratory facility. The clean laboratory techniques (Davidson, 1979) were necessitated because of the low flow rates which varied between 900 and 1000 cc min^{-1} per sample and the expected low elemental concentrations at each of these sampling sites.

Contamination of air samples is minimized after collection by wrapping each filter in precleaned polyethylene bags. The heads are triple bagged prior to transport to the laboratory.

Water samples are collected by two different methods. At each sampling site, a 250-ml grab sample is collected from a nearby stream. The sample is placed in an acid-washed polyethylene bottle and fixed with 5 ml of Ultrex nitric acid per 100 ml of sample. At four sites, a gravity flow resin column was used. This column, packed with selected resin filters for entrapping organic compounds, is placed in the river or stream to be sampled. Natural water flow forced water through the column. The resins selected for this water sampling device are described by Wiersma *et al.* (1979).

Vegation, soil, and litter were collected at seven locations. The design and the number of samples collected are based upon previously defined factors and limitations as described by Wiersma *et al.* (1979), and Wiersma and Brown (1979). At each collection location, five different plant species are collected from 10 different subsites (Figure 2). Therefore, a total of 50 plant samples, representing 10 replications of 5 different species, are collected for analysis. In addition, one soil sample (0–5 cm in depth) and one litter sample was collected from each of the subsampling sites, making a total of 10 samples each per sample site. The 50 plant, 10 soil, and 10 litter samples are placed in clean polyethylene bags and sealed. All of these samples are analyzed for trace elements. One soil and one litter sample collected from one of the subsites are placed in clean 1-liter Teflon® bottles for organic analysis.

3. Sampling Locations

3.1. High altitude air sampling sites

Three different sites were selected for high altitude air sampling. As shown on Figure 1, the sites are fairly evenly distributed in the higher elevations of the park. The

first site was located on the ridge above Moose Lake, with access via the ridge line or by the Grand Pass Trail from Hurricane Ridge. The second site is located about 900 meters south of the Glacier Meadows ranger station near the eastern edge of the Blue Glacier moraine. The third site is located about 1800 meters west of Anderson Pass and 400 meters south of the Anderson Pass Trail.

The following criteria were used for site selection:

1. free of local contamination and at least 5 km from the nearest road used by automobiles and other motorized vehicles,
2. located at as high an elevation as possible, and
3. located in a clearing whose diameter is at least five time the height of the surrounding forest.

The sampling heads at these three sites are supported by an aluminum stand. The heads were 1.5 meters from the ground. The pumps, battery and flow meters are placed on the ground during operation.

3.2. Water sampling sites

Four different major drainage systems were chosen for the resin filter collectors. Grab samples, as previously described for elemental analysis, are also collected in these drainage systems. The drainages samples included the Elwha, Hoh, Quinault and the Dosewallips as shown on Figure 1. These four drainage systems drain more than 50 percent of the park's watersheds. The length of sampling varied from 5 to 8 days.

Surface snow samples were collected for trace element analysis from the Blue Glacier. The location of this collection site as shown on Figure 1 is on the eastern edge of the glacier near its midpoint.

3.3. Multimedia sampling sites

At these sites (Figure 1), air, water, vegetation, soil and litter are collected. The air monitoring equipment and techniques used for sampling air in these locations is identical to those used for high altitude air sampling sites. At these sites the filter holders are placed under the vegative canopy and supported by young saplings. The number of samples and the techniques used for sampling vegetation, soil, and litter are previously described. Grab samples of water are collected from small streams for each sampling location.

3.4. Low altitude Hoh

This site is located on the north side of the Hoh River approximately 1800 meters west of the Olympus shelter. It is dominated by Sitka spruce, *Picea sitchensis,* and western hemlock, *Tsuga heterophylla.* As described by Franklin and Dyrness (1973), the distinctive characteristics of this forest are (1) an abundance of *Acer macrophyllum* and *A. circinatum;* (2) conspicuous coverage of epiphytic plants, (3) abundant nurse logs; and (4) heavy seasonal visitation by Roosevelt elk *(Cervis canadensis var. roosevelti).*

Plant species collected included:

1. *Acer circinatum*	vine maple
2. *Tiarella trifoliata*	foam flower
3. *Oxalis oregana*	wood sorrel
4. *Polystichum munitum*	sword fern
5. *Rhytidiadelphus loreus*	moss

3.5. High altitude Hoh

This area is located about 2000 meters north of the Glacier meadows shelter and west of the Hoh trail. It is dominated by mountain hemlock, *Tsuga mertensiana* with areas of silver fir *Abies amabilis*. This vegetative type usually dominates the higher forested zones along the western slopes of the Olympic National Park.

Chamaecyparis nootkatensis is a major associate, with *Pseudotsuga menziesii, Abies lasiocarpa* and *Pinus monticola* being minor associates. There is a wide variety of understory species, many of which belong to the Ericaceae, Rosaceae, and Compositae families.

Species collected included:

1. *Vaccinium ovalifolium*	oval-leaf huckleberry
2. *Vaccinium membranaceum*	thin-leaved huckleberry
3. *Vaccinium alaskaense*	Alaska huckleberry
4. *Rubus pedatus*	blackberry
5. *Streptopus streptopoides*	twisted-stalk

3.6. Ocean site (Ozette)

This site is located about 5000 meters southwest of the Ozette trail head to Sand Point. The vegetative type is a western hemlock-Sitka spruce/*Goultheria shallon*, salal, association (Franklin and Dyrness, 1973). It is commonly found along coast lines and includes a dense shrub layer of salal. Salal commonly contributes over 40% of the species composition. Other common species include *Oxalis oregana* and *Thuja plicata*.

Species collected included:

1. Moss species	(genus and species unidentified)
2. Fern species	(genus and species unidentified)
3. *Lysichitum americanum*	skunk cabbage
4. *Vaccinium ovatum*	evergreen huckleberry
5. *Gaultheria shallon*	salal

3.7. Low altitude Quinault

This area is located 2000 meters northeast of the Enchanted Valley trail head near the east fork of the Quinault River. The forest is dominated by Douglas fir, *Pseudotsuga menziesii* and western hemlock. It has a rich abundance of understory species including grasses, ferns and a wide variety of mosses.

Species collected included:

1. *Maianthemum dilatatum*	beadruby
2. *Pteridium aquilinum*	—
3. *Cornus canadensis*	dogwood
4. *Clintonia uniflora*	queens cup
5. *Vaccinium parvifolium*	huckleberry

3.8. High altitude Quinault

This sampling area is located 50 meters north of the Enchanted Valley Trail, approximately 1800 meters northeast of the Chalet shelter. Vegetation is characterized and dominated by western hemlock. Associated species include Douglas fir and *Thuja plicata*. Shrubs such as *Alnus rubra*, *Acer macrophyllum* and *Castanopsis chrysophylla* are widespread.

Species collected included:

1. *Vaccinium alaskaense*	huckleberry
2. *Tiarella trifoliata*	foam flower
3. *Rubus spectabilis*	blackberry
4. *Lobarium oregonum*	—
5. Moss species	—

3.9. Low altitude Dosewallips

This area is located about 2500 meters west of the Dosewallips trail head on the west fork of the Dosewallips River. It is dominated by western hemlock and Douglas fir. The vegetative aspect is similar to the high Quinault sampling site.

Species collected included:

1. Moss species	—
2. *Polystichum* species	fern
3. *Berberis nervosa*	Oregon grape
4. *Gaultheria shallon*	salal
5. *Rhododendron* species	rhododendron

3.10. High altitude Dosewallips

This area is located 2500 meters northeast of the Anderson Pass shelter on the west fork of the Dosewallips River. The dominant species and the vegetative aspect are similar to the high altitude Hoh sampling site.

Species collected included:

1. Moss species	—
2. *Abies amabilis*	silver fir
3. *Ribes species*	gooseberry
4. *Vaccinium ovalifolium*	oval-leaf huckleberry
5. *Vaccinium membranaceum*	thin-leaved huckleberry

4. Analytical Techniques

Analytical methods, procedures and techniques used for each sample type have been previously described (Wiersma *et al.*, 1979) and (Wiersma and Brown, 1979). Table I shows the analytical methods that are being utilized for the analysis of the Olympic National Park samples.

TABLE I

Analytical methods utilized for the analysis of the Olympic National Park samples.

Sample Type	Analytical Method	Analysis
Water	Gas Chromatograph- Mass Spectrometry (GC–MS)	Purgeable Organics Non Purgeable Organics
Water	Inductively Coupled Plasma Emission (ICEPS) Spark Source Mass Spectrometry (SSMS)	Multi-element
Air	X-ray fluorescence	Multi-element
Scanning Electron Microscope (SEM)	Particle sizing and composition	
	Atomic absorption spectrometry	Elemental
Vegetation/litter	Spark Source Emission Spectroscopy (SSES)	Multi-element
Litter	Gas chromatography	Pesticides
Soils	Atomic absorption spectrometry/ gas chromatography	Elemental/pesticides

5. Results

Part of the data from Olympic National Park are shown below. Table II shows the results for trace elements in streams and compares them to data from the Great Smoky Mountains streams sampled in 1978.

In general the results are quite similar. Particularly if one ignores differences due to increased detection limits. However, there are a few exceptions. First calcium levels

are considerably higher in the Olympics than in the Smokys, and low levels of titanium and zinc were found in the Smokys but not the Olympics.

TABLE II

Comparison of trace elements in Great Smoky Mountains and Olympic National Park streams: μg ml^{-1} (% of samples).

Element	Smokys 1978	Olymics 1979
Aluminum	0.05 (48)	0.01 (50)
Barium	0.008 (100)	0.003 (100)
*Cadmium	< 0.005	0.0004 (12)
*Calcium	1.8 (100)	15.8 (100)
Iron	0.16 (95)	0.008 (25)
Magnesium	0.40 (100)	1.2 (100)
Manganese	0.035 (81)	0.003 (50)
Sodium	< 5	2.0 (100)
Strontium	0.009 (100)	0.114 (100)
*Thorium	0.008	0.009 (100)
Titanium	0.001 (14)	< 0.0001
Zinc	0.03 (14)	< 0.0005

* Detection limit increased in 1979.

Surface snow from the Blue Glacier was collected and analyzed using the same techniques as for streams. The results are shown in Table III. Because of the limited sampling, the results should be viewed with caution. The Glacier was resampled in the summer of 1980, but these results are not available at this time. There is a striking increase in the number of elements detected. Many of the new elements have suspected or proven long-term transport characteristics such as mercury, selenium, vanadium, lead and zinc. Whether the snow is serving as a collection point for trace elements into the park, or the data is an artifact, cannot be answered at this time, but the possibilities must be explored.

TABLE III

Trace elements in Blue Glacier sample, Olympic National Park, 1979: (μg ml^{-1}).

Element	Concentration	Element	Concentration
*Aluminum	0.92	Iron	1.19
*Barium	0.006	Mercury	0.010
*Calcium	0.31	Nickel	0.007
*Magnesium	0.21	Lead	0.014
*Manganese	0.054	Antimony	0.008
*Sodium	0.12	Selenium	0.008
*Strontium	0.003	Titanium	0.059
Cobalt	0.005	Vanadium	0.002
Chromium	0.001	Yttrium	0.002
Copper	0.007	Zinc	0.005

* Found in streams.

TABLE IV

Moss samples from Olympic National Park, 1979: ($\mu g\ g^{-1}$).

Site	Copper	Titanium	Lead
Ozette	1.6	126	0.8
High Quinault	3.8	53	0.4
High Dosewallips	4.5	66	2.2
Low Dosewallips	7.9	58	19.6

Moss samples from four sites in the Olympics are shown in Table IV for three trace elements. In general the levels are relatively low for copper and lead. The one exception is the lead value for the low Dosewallips site. Of the four sites listed, this site was the closest to a rather large and well used parking lot and campground.

Table V compares forest litter samples for all seven sites in the Park for copper, titanium and lead. Once again high lead levels are found only at the low Dosewallips site. Relatively higher levels of copper were also found at that site. In 1980, this area was resampled and additional sampling sites were selected further up the valley to determine a possible gradation of lead up the Dosewallips Valley.

TABLE V

Litter samples from Olympic National Park, 1979: ($\mu g\ g^{-1}$)

Site	Copper	Titanium	Lead
Low Hoh	6.2	87	1.5
High Hoh	12.7	192	0.9
Ozette	6.2	270	4.5
Low Quinault	10.1	314	9.6
High Quinault	10.9	194	2.6
High Dosewallips	7.5	108	2.0
Low Dosewallips	16.3	237	95.5

6. Conclusions

The collection and assessment of biological and physical samples from selected areas of the Olympic National Park will be used to develop a pollutant monitoring system. The techniques used, associated with long-term monitoring data, will serve to identify baseline levels, identify pollutant concentrations, determine trends, and define the physical and biological responses to manmade contaminants.

The preliminary results in this paper tend to incidate that the Olympics may be a relatively 'clean' biosphere reserve. Wiersma and Brown (1980) have pointed out for certain trace elements no true background level may exist today. Perhaps the best can be expected is the establishment of reliable reference levels through the use of remote areas such as biosphere reserves. The difference in kinds of trace elements found in the Blue Glacier compared to the Olympic streams should be thoroughly investigated.

References

Ad Hoc Task Force on GNEM: 1970, 'A Global Network for Environmental Monitoring', A *Report* to the Executive Committee, U.S. National Committee for the International Biological Program.

Barry, P. S.: 1979, 'An Introduction to the Exposure Commitment Concept with Reference to Environmental Mercury', *MARC Report Number 12*. Monitoring and Assessment Research Center. Chelsea College, University of LMondon, London.

Brown, K. W., Wiersma, G. B., and Frank, C. W.: 1979, 'A Battery-Operated Air Sampler for Remote Areas'. EPA-600/4-79-071. U.S. Environmental Protection Agency, Las Vegas, Nevada.

Davidson, C.: 1979, Assistant Professor Civil Engineering and Engineering Public Policy Carnegie-Mellon Univ. Pittsburgh, Penn. Personal Communication.

Franklin, Jerry F. and Dyrness, C. T.: 1973, 'Natural Vegetation of Oregon and Washington', Pacific Northwest Forest and Range Experiment Station. PNW-8. Portland, Oregon.

Moorehead, B.: 1979, Research Biologist Olympic National Park, Port Angeles, Wash. Personal communication.

Morgan, G. B., Wiersma, G. B., and Barth, D. S.: 1979, 'Monitoring on Biosphere Reserves for Regional Background Levels of Pollutants', *Proceedings of the United States – Union of Soviet Socialist Republics Symposium on Biosphere Reserves. Moscow USSR.* May 1976. Pacific Northwest Forest and Range Experiment Station. General Technical Report PNW-82, pp. 90–104.

O'Brien, B. J.: 1979, 'The Exposure Comitment Method with Application to Exposure of Man to Lead Pollution', *MARC Report No. 13*. Monitoring and Assessment Research Center. Chelsea College, University of London, London.

Schuck, E. A. and Morgan, G. B.: 1975, 'Design of Pollutant Oriented Integrated Monitoring Systems', International Conference on Environmental Sensing and Assessment, Paper No. 20–6. Las Vegas, Nevada. September, 1975.

Wiersma, G. B.: 1979, 'Kinetic and Exposure Commitment Analyses of Lead Behavior in a Biosphere Reserve'. *MARC Report No. 15*. Monitoring and Assessment Research Center. Chelsea College, University of London, London.

Wiersma, G. B. and Brown, K. W.: 1979, 'Recommended Pollutant Monitoring System for Biosphere Reserves', published in *Proc. Second Conf. on Scientific Research in the Natinal Parks*. San Francisco, California. November, 1975.

Wiersma, G. B., Brown, K. W., Herrmann, R., Taylor, C., and Pope, J.: 1979, 'Great Smoky Mountains Preliminary Study for Biosphere Reserve Pollutant Monitoring', EPA-600/4-79-071. U.S. Environmental Protection Agency, Las Vegas, Nevada.

Wiersma, G. B. and Brown, K. W.: 1980, 'Background levels of trace elements in forest ecosystems', presented at the International Symposium on effects of air pollutants on mediteranean and temperate forest ecosystems, June 22–27, 1980. Riverside, California.

Wiersma, G. B., Frank, C. W., Brown, K. W., and Davidson, C. I.: 1980, 'Lead particles in the Great Smoky Mountains Biosphere Reserve', EPA-600/4-80-002. U.S. Environmental Protection Agency, Las Vegas, Nevada.